PATENT SPECIFICATION

DRAWINGS ATTACHED

869,397

Date of Application and filing Complete Specification: June 29, 1959.

No. 22167/59.

Application made in United States of America on July 2, 1958.

Complete Specification Published: May 31, 1961.

Index at acceptance:—Class 82(2), V(2T: 3C: 3E: 4H: 4N: 4W).

International Classification:—C23c.

COMPLETE SPECIFICATION

Method and Apparatus for Filming Articles by Vacuum Deposition

We, LIBBEY-OWENS-FORD GLASS COMPANY, a Corporation organized under the laws of the State of Ohio, United States of America, of 608 Madison Avenue, City of Toledo, County of Lucas and State of Ohio, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to apparatus for filming articles as well as methods for producing these articles. More particularly, it is concerned with the production of heat rejecting plate glass or other transparent material by a vacuum evaporation method.

The use of a heat rejecting coating on glass windows is desirable in both buildings and automobiles not only because such films reject the heat but also because less heat is absorbed by the window itself, and this is important in the case of double glazed units wherein absorbed heat may be trapped both in the glass elements and in the air space therebetween. The reduction of the heat absorbed by these elements reduces the load on air conditioning equipment inasmuch as little trapped heat is present to be reradiated into the building.

However, it has not been practical in the past to produce a glazing unit which has been coated with a heat rejecting film of such a size as to be practical in both buildings and automotive vehicles. One of the primary difficulties encountered in the production of such coated glass sheets was the fact that the coating chamber had to be evacuated each time a window was to be coated and such an operation was not only time consuming but also prohibitively expensive because of the large number of the coating chambers required to contain sheets of glass of the size used in glazing units.

In the accompanying drawings:

Fig. 1 is a schematic view of the filming unit with the various vacuum chambers used in carrying out the method of the present invention and shows a pair of glass sheets after they have entered the unit;

Fig. 2 is a schematic view similar to Fig. 1 but showing the position of the glass sheets while they are being heated during the cleaning portion of the cycle;

Fig. 3 is a schematic view similar to Fig. 1 but showing the position of the glass sheets while they are being cleaned by a glow discharge;

Fig. 4 is a schematic view similar to Fig. 1 and showing the position of the glass sheets during the first coating portion of the cycle;

Fig. 5 is a schematic view similar to Fig. 1 showing the position of the glass sheets during the second coating portion of the cycle;

Fig. 6 is a schematic view similar to Fig. 1 but showing the position of the glass sheets prior to being discharged from the unit;

Fig. 7 is an alternative embodiment of the present invention in which space between the glass sheets is increased and the evaporant sources are positioned between the sheets;

Fig. 8 is another embodiment of the present invention in which the glass sheets are passed through pairs of parallel vacuum chambers; and

Fig. 9 is still another embodiment of the invention which utilizes filming sources along the outer walls of the coating chamber.

According to the present invention a method of coating sheets in an evacuated vacuum chamber containing a source of thermally evaporated metal and having an intake chamber and a discharge chamber operatively connected to said vacuum chamber and adapted for selective communication therewith without destroying the vacuum in said chamber, is characterized by the steps of sealing an entire sheet to be coated within the intake chamber while said chamber is at atmospheric pressure, simultaneously evacuating said intake chamber and cleaning a surface of the sheet to be coated while the sheet is sealed therein,

[*Price 3s. 6d.*]

Price 33p

establishing communication between the intake chamber and the vacuum chamber after the intake chamber has been evacuated, transferring the sheet from the evacuated intake chamber into the vacuum chamber through said open communication, closing the communication between said intake chamber and said vacuum chamber, coating the sheet in said vacuum chamber while evacuating the discharge chamber, establishing communication between the vacuum chamber and the discharge chamber after the sheet has been coated and the discharge chamber has been evacuated, transferring the coated sheet from the vacuum chamber to said evacuated discharge chamber through said open communication, sealing the coated sheet in said discharge chamber by closing the communication between the vacuum chamber and said discharge chamber, increasing the pressure in said discharge chamber to atmospheric pressure, and then removing the coated sheet therefrom.

The invention also provides apparatus for carrying out the method of the present invention comprising a plurality of interconnected chambers including an intake chamber, a vacuum chamber and discharge chamber, characterized by the fact that an intermediate chamber is positioned between said intake chamber and said vacuum chamber and adapted to communicate therewith, an auxiliary chamber located within the intermediate chamber, and a glow discharge means positioned within said auxiliary chamber, valves separating said intake chamber, intermediate chamber, vacuum chamber and discharge chamber from one another for selectively establishing and preventing communication therebetween, and a carrier for supporting the sheet to be coated for movement through said chambers, including the auxiliary chamber, when communication therebetween has been established.

With reference now to the drawings and particularly to Figs. 1 to 6, there is schematically shown an evacuated filming apparatus 20 comprising an intake chamber 21, an intermediate or cleaning chamber 22, a vacuum or coating chamber 23 and a discharge chamber 24 which are separated by valves that seal the chambers from one another or from the atmosphere when closed and establish communication therebetween when open. While the intake chamber 21 is at atmospheric pressure an air dryer 25 continuously purges this section of the filming unit 20 with dry air.

The intake chamber 21 is sealed from the atmosphere by means of an inlet vacuum valve 26 and is further sealed from the cleaning chamber 22 by means of the vacuum valve 27. When valves 26 and 27 are closed, the pressure in chamber 21 is reduced from atmospheric to 10^{-3} mm Hg by suitable vacuum pumps 28 and during the first portion of the evacuation air is blown downwardly across the surface to be filmed from suitable air guns 29 to remove dust and lint therefrom. An electrical dust collector is installed in the intake chamber to collect the dust and lint which is removed by the blast from the air gun 29. To prevent a static charge from being built up on the surface which is being cleaned Plutonium probes 31 are used in conjunction with the air guns 29 to neutralize the electrical charge on this surface thereby preventing foreign particles such as dust and lint from settling thereon.

In order to shorten the production cycle it is sometimes advantageous to commence the heating of the article to be filmed in the intake chamber 21 to provide sufficient time to heat the article to the required temperature. This heating is supplied by suitable heating elements 32 which may be space heaters or coils of high temperature or non-sputtering resistance wire located within chamber 21. Heating during the first portion of the evacuation not only provides additional heating time but also provides more efficient heating because the article is heated by convection as well as by radiation.

Heating elements 33 similar to heating elements 32 are positioned within that portion of the cleaning chamber 22 which lies adjacent the vacuum valve 27. An inner chamber 34, preferably of aluminium or titanium sheet metal, is positioned at the opposite end of the cleaning chamber 22 which is adiacent the coating chamber 23, and this inner chamber forms a box that fits closely to the article and confines the glow during the cleaning operation. A glow plate 35 which may be aluminium or other non-sputtering metal is positioned between the surfaces to be coated. Thus, the glow is largely confined to the area surrounding the glow plate 35 by the articles within the inner chamber 34.

The cleaning chamber 22 is considerably larger than the intake chamber 21 as seen in Figs. 1 to 6 and suitable vacuum pumps 36 maintain chamber 22 at a relatively low pressure of 10^{-4} mm Hg during transfer times and at a higher chamber pressure which may be in the range of 1 to 10 microns Hg while oxygen is introduced therein through the pipe 37 for a relatively high voltage glow discharge cleaning cycle. In order to separate the cleaning chamber 22 from the coating chamber 23 and establish a communication therebetween a vacuum valve 38 is installed therebetween.

The relatively large coating chamber 23 lies adjacent to the cleaning chamber 22 at the opposite end from the intake chamber and this chamber is of sufficient size so that any object being filmed may be located at least 40 inches away from the evaporant sources 39 and 40. This unusually great distance decreases the number of evaporant sources required and a baffle 41 prevents the evaporants from one source from depositing on the surface of an article when it is in the position to receive evaporants from the other source.

More particularly, as seen in Fig. 5, the baffle 41 is positioned between the sources 39 at right angles to the path of travel of the articles to be coated and extends transversely across the coating chamber 23 a distance great enough to prevent the source 39 from "seeing" the surface of the articles on carriers *A*. Likewise the source 40 cannot "see" the surface of the articles on carriers *B*, however, the baffle 41 does not extend laterally to a point where it would prevent the forward movement of the articles through the filming apparatus 20. It is to be understood that the size of the baffle 41 will depend upon the spacing and the size of the sources 39.

The coating chamber 23 is equipped with suitable locks 42 for introducing and removing the evaporant source 39 and 40 from the filming unit. Vacuum pumps 43 maintain the coating chamber at a pressure of less than 10^{-5} mm Hg throughout the entire coating cycle while vacuum pumps 44 evacuate the locks 42 to permit the evaporant sources to be moved into the coating chamber 23.

The coating chamber 23 is separated from the discharge chamber 24 by means of a vacuum valve 45 which prevents the vacuum in the coating chamber 23 from being destroyed when the pressure within the discharge chamber 24 is raised to atmospheric pressure. The discharge chamber 24 is similar to the intake chamber 21 and is separated from the atmosphere by means of the vacuum valve 46. Suitable vacuum pumps 47 serve to evacuate this chamber.

According to the method of the present invention the transparent sheets 48 are placed upon a suitable carrier 49 such as a dolly or conveyor as shown schematically in Figs. 1 to 6 and the intake vacuum valve 26 is opened to permit the sheets 48 and the carrier 49 as indicated by *A* to move into the intake chamber 21 at which time the intake vacuum valve 26 is then closed is shown in Fig. 1. The intake chamber 21 is then evacuated by pumps 28 and during the first portion of this evacuation it is necessary to bleed in clean dust-free gas to prepare the surfaces for coating by blowing the sheets by means of the guns 29 to remove any residual lint or dust particles. The gas flow is controlled to maintain a high enough pressure in order that the dust collector 30 may be used to collect the lint or dust. The air guns 29 and the dust collector 30 are shut off simultaneously after a brief blow-off period of preferably less than one minute. The sheets may also be heated by the heating elements 32 and the Plutonium probes 31 prevent static charges from being built up on the surfaces of the sheets 48.

After the intake chamber 21 has been evacuated to 10^{-3} mm of Hg. the valve 27 separating the intake chamber 21 from the cleaning chamber 22 is opened to permit the sheets 48 to be moved out of the intake chamber 21 and into the cleaning chamber 22 which has previously been evacuated to 10^{-4} mm of Hg. Upon entering this chamber the sheets 48 are positioned in close proximity to the heating elements 33 as shown in Fig. 2 for further heating and the separating vacuum valve 27 is closed at which time the intake chamber 21 is permitted to assume atmospheric conditions to receive a second carrier unit *B*. The air dryer 25 continuously purges this chamber with dry air while at atmospheric pressure to prevent the absorption of water vapour on the chamber surfaces thereby assisting the evacuating operation.

The cleaning chamber 22 is maintained at a vacuum of either 10^{-4} mm Hg or 1 to 10 microns Hg and the sheets 48 are heated in either vacuum to the desired temperature which may be 500° F. by means of the heating elements 33. While the sheets on carrier *A* are being heated prior to glow cleaning, a second carrier *B* is moved into the intake chamber 21 as previously described in connection with carrier *A*.

After the sheets on carrier *A* have been heated, they are moved to the glow portion of the cleaning chamber 22 which comprises the inner chamber 34 which fits closely around the sheets. Oxygen is bled into the chamber from the pipe 37 to maintain a desired vacuum having a pressure for example in the range of 1 to 10 microns Hg for a relatively high voltage glow discharge which may be 1500 volts using a non-sputtering material and the sheets 48 are thereby sufficiently cleaned without contaminating their surfaces. Before the sheets of the carrier *A* are cleaned by the glow discharge the carrier unit *B* is moved into the cleaning chamber through the vacuum valve 27 as shown in Fig. 3, and a third carrier *C* is moved into the intake chamber 21.

After the sheets have been cleaned by the glow discharge the vacuum valve 38 on the entrance side of the coating chamber 23 is opened and the carrier *A* is moved into the coating chamber 23 as shown in Fig. 4. Also carrier *B* is moved into the inner chamber 34 and carrier *C* enters cleaning chamber 22 for heating while loaded carrier *D* is likewise moved into intake chamber 21. It is understood that the carriers 49 are automatically moved sequentially to the respective work stations as the vacuum valves are opened and the vacuums are not changed for any appreciable period of time.

According to the preferred embodiment of the present invention, the evaporant sources 39 and 40 are accurately positioned in the center of the coating chamber 23 and the sheets 48 are positioned along the walls thereof which permits the coating material to evaporate from both sides of the sources 39 and 40 thereby reducing waste. By accurately positioning the sources 39 and 40 equidistant between the sheets 46 the films deposited on the sur-

faces of these sheets are assured of being the same thickness.

In order to place the sheets 48 adjacent the walls of the coating chamber 23, the carrier 49 carrying the sheets 48 first enter the chamber 23 through the vacuum valve 38 and then are indexed or shifted outwardly to positions adjacent oppositely disposed walls of chamber 23 as shown in Fig. 4. After the vacuum valve 38 is closed, the sheets are coated by vacuum evaporation from source 39 for as long as necessary to produce the coating desired at the coating position. Following the first portion of the filming cycle the carrier 49 and sheets 48 are then moved to the second position in the coating chamber 23 for the second predetermined coating cycle if desired using source 40 as shown in Fig. 5 while carriers *B, C, D* and *E* also automatically advanced.

After the sheets 48 have been coated, the vacuum valve 45 is opened and the unit is moved into the discharge chamber 24 which has been evacuated to 10^{-3} mm Hg by vacuum pumps 47 as shown in Fig. 6. Upon closing the vacuum valve 45 the discharge chamber 24 is raised to atmospheric pressure and the exit vacuum valve 46 is opened thereby permitting the carrier 49 and coated sheets 48 to be discharged from the coating chamber 24 while the other carriers are each sequentially advanced.

Figs. 7, 8 and 9 show alternate embodiments of the apparatus utilized in carrying out the method of the present invention and like numerals are used to indicate like elements throughout the same. More particularly, there is shown in Fig. 7 a filming unit 20 in which the intake chamber 50, the cleaning chamber 51 and the discharge chamber 52 are substantially the same width as the coating chamber 23 and are separated by exceptionally large valves 53, 54, 55, 56 and 57. This increased width permits the carriers 49 carrying the sheets 48 to move along a path which is parallel and adjacent opposed walls of the unit 20 through the respective chambers and the step of indexing the carriers and sheets outwardly from the centerline of the unit 20 as these elements enter the coating chamber 23 through the valve 55 is eliminated.

Fig. 8 shows still another embodiment of the invention wherein a single large coating chamber 23 with evaporant sources 39 and 40 positioned substantially in the center thereof equidistant between the sheets 48 is utilized with parallel pairs of intake chambers 58, cleaning chambers 59 and discharge chambers 60 separated by relatively small valves 61, 62, 63, 64 and 65. Not only does this eliminate the outward indexing of the carriers 49 in the coating chamber 23 but also the volumes of chambers 58, 59 and 60 are decreased thereby permitting faster evacuation of these portions of the unit 20.

Still another embodiment of the invention is illustrated in Fig. 9 wherein the evaporant sources 39 and 40 and the locks 42 are placed adjacent the outermost walls of the coating chamber 23 and the carrier 49 supporting the sheets 48 is moved substantially along the center line of the filming unit 20. Not only does this eliminate the indexing of the carrier 39 in the coating chamber but also permits a single carrier 49 to support a plurality of sheets 48 while obtaining the advantage of the smaller intake chamber 21, cleaning chamber 22, and discharge chamber 24.

It is to be understood that the filming unit 20 is highly flexible and may be used for filming light transmissive and reflective mirrors; dichroic mirrors; transparent mirrors; interference filters; light and heat filters; low reflection, electrically conducting and graded coatings; as well as heat rejection glass. Also films can be deposited by the present method on opaque and semitransparent material, such as metal and plastics, as well as glass and other glassy siliceous material.

WHAT WE CLAIM IS:—

1. A method of coating sheets in an avacuated vacuum chamber containing a source of thermally evaporated metal and having an intake chamber and a discharge chamber operatively connected to said vacuum chamber and adapted for selective communication therewith without destroying the vacuum in said vacuum chamber, characterized by the steps of sealing an entire sheet to be coated within the intake chamber while said chamber is at atmospheric pressure, simultaneously evacuating said intake chamber and cleaning a surface of the sheet to be coated while the sheet is sealed therein, establishing communication between the intake chamber and the vacuum chamber after the intake chamber has been evacuated, transferring the sheet from the evacuated intake chamber into the vacuum chamber through said open communication, closing the communication between said intake chamber and said vacuum chamber, coating the sheet in said vacuum chamber while evacuating the discharge chamber, establishing communication between the vacuum chamber and the discharge chamber after the sheet has been coated and the discharge chamber has been evacuated, transferring the coated sheet from the vacuum chamber to said evacuated discharge chamber through said open communication, sealing the coated sheet in said discharge chamber by closing the communication between the vacuum chamber and said discharge chamber, increasing the pressure in said discharge chamber to atmospheric pressure, and then removing the coated sheet therefrom.

2. A method of coating sheets as claimed in claim 1, characterized by the fact that the vacuum chamber is maintained at a pressure of less than 10^{-3} mm Hg.

3. A method of coating sheets as claimed in either of claims 1 or 2, characterized by the fact that the intake chamber is evacuated while the sheet is sealed therein to a pressure of 10^{-3} mm Hg.

4. A method of coating sheets as claimed in any of claims 1 to 3, characterized by the fact that the intake chamber is continuously purged with dry air when said intake chamber is at atmospheric pressure.

5. A method of coating sheets as claimed in any of claims 1 to 4, characterized by the fact that the surface of the sheet to be coated is cleaned by subjecting said surface to a blast of clean dust-free gas immediately after sealing the sheet in the intake chamber and while simultaneously evacuating said chamber.

6. A method of coating sheets as claimed in claim 5, characterized by the fact that the surface of the sheet is subjected to the blast of clean dust-free gas for a period of less than one minute.

7. A method of coating sheets as claimed in any of claims 1 to 6, characterized by the fact that the static charge on the surface of the sheet to be coated is neutralized while the sheet is sealed in the intake chamber.

8. A method of coating sheets as claimed in any of claims 1 to 7, characterized by the fact that the sheet to be coated is heated while the sheet is sealed in the intake chamber.

9. A method of coating sheets as claimed in any of claims 1 to 8, characterized by the fact that the sheets to be coated is transferred from the intake chamber into an intermediate chamber located between the intake chamber and the vacuum chamber prior to transferring the sheet into the vacuum chamber for coating, sealing said sheet within said intermediate chamber, and subjecting the sheet to a relatively high voltage glow discharge while sealed therein.

10. A method of coating sheets as claimed in claim 9, characterized by the fact that the intermediate chamber is maintained at a pressure of 10^{-4} mm Hg during transfer times and in the range of 1 to 10 microns Hg during the time the sheet is subjected to said high voltage glow discharge.

11. A method of coating sheets as claimed in either of claims 9 or 10, characterized by the fact that the sheet to be coated is heated while the sheet is sealed within the intermediate chamber.

12. A method of coating sheets as claimed in any of claims 1 to 11, characterized by the fact that the sheet is positioned at a plurality of predetermined stations in the vacuum chamber, and coating the sheet while positioned at each of said stations.

13. A method of coating sheets as claimed in any of claims 9 to 12, characterized by the fact that a second sheet to be coated is sealed within the intake chamber immediately after the first-mentioned sheet has been moved therefrom into the intermediate chamber.

14. Apparatus for carrying out the method of claims 1 to 13, comprising a plurality of interconnected chambers including an intake chamber, a vacuum chamber and a discharge chamber, characterized by the fact that an intermediate chamber is positioned between said intake chamber and said vacuum chamber and adapted to communicate therewith, an auxiliary chamber located within the intermediate chamber, and a glow discharge means positioned within said auxiliary chamber, valves separating said intake chamber, intermediate chamber, vacuum chamber and discharge chamber from one another for selectively establishing and preventing communication therebetween, and a carrier for supporting the sheet to be coated for movement through said chambers, including the auxiliary chamber, when communication therebetween has been established.

15. Apparatus as claimed in claim 14, characterized by the fact that the chambers have a common centerline, and the carrier is positioned to convey the sheets through the chambers along a path which is located at or near the common centerline of said chambers.

16. Apparatus as claimed in claim 14, characterized by the fact that the carrier is positioned to convey the sheets through the intake and intermediate chambers along a path which is located at or near the centerline thereof, means for mounting said carrier for transverse movement relative to the centerline of the chambers and adapted to move the sheets through the vacuum chamber along a path which is located adjacent and along a side wall of the vacuum chamber.

17. Apparatus as claimed in claim 14, characterized by the fact that the carrier is positioned to move the sheets through the chambers along a path which is located adjacent and along the side walls of the chambers.

18. A method of coating sheets as described in the specification.

19. Apparatus for coating sheets as described in the specification with reference to the accompanying drawings.

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Leamington Spa: Printed for Her Majesty's Stationery Office, by the Courier Press.—1961.
Published by The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

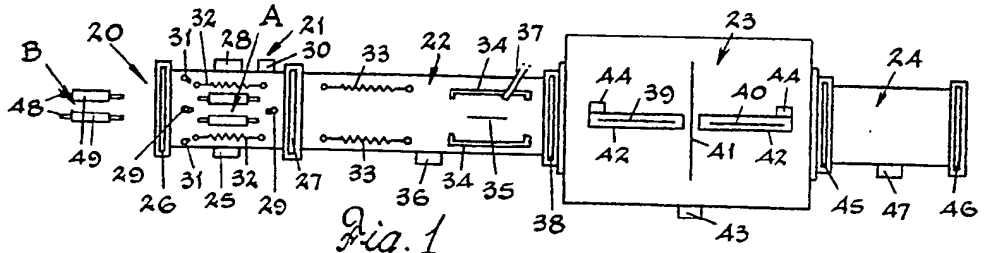

Fig. 1

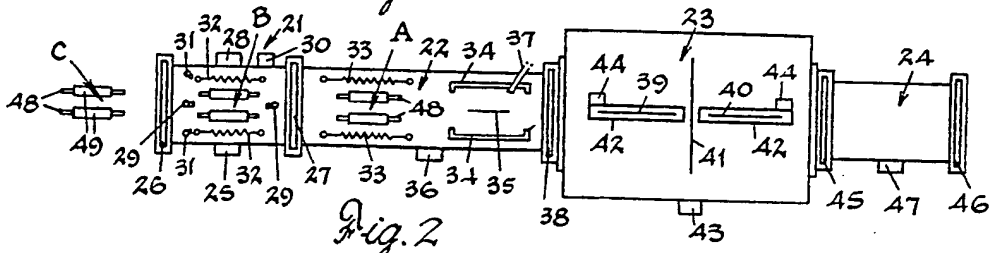

Fig. 2

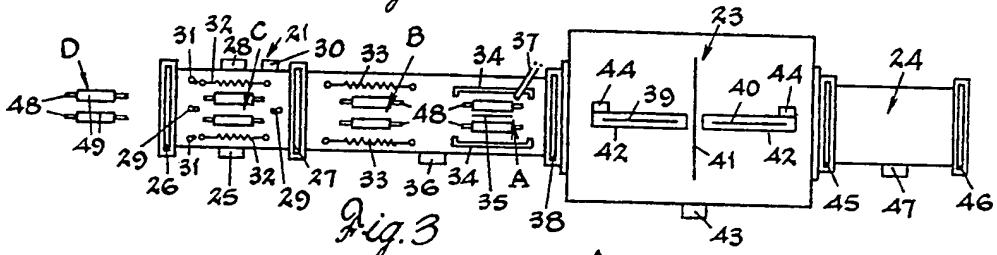

Fig. 3

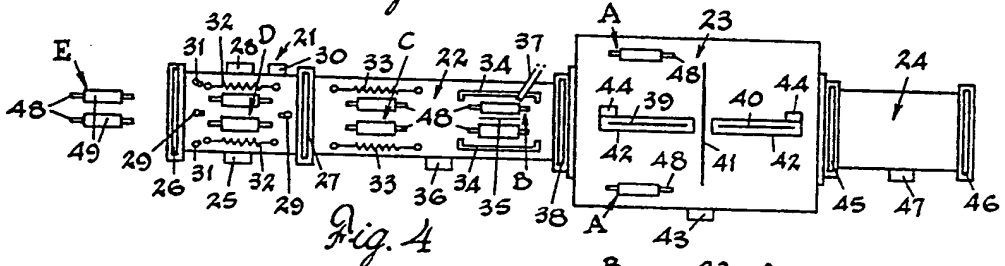

Fig. 4

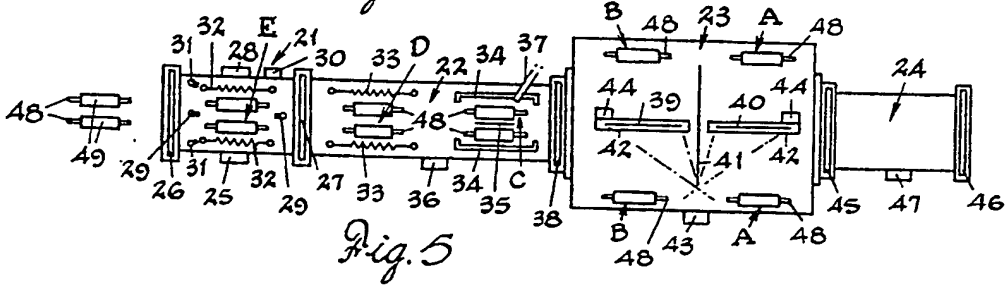

Fig. 5

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2 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

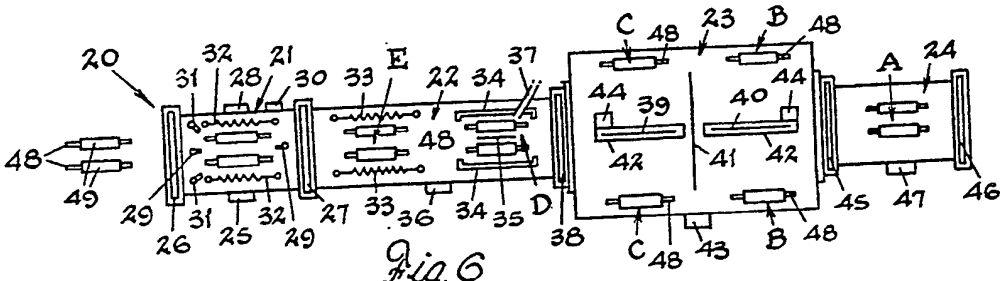

Fig. 6

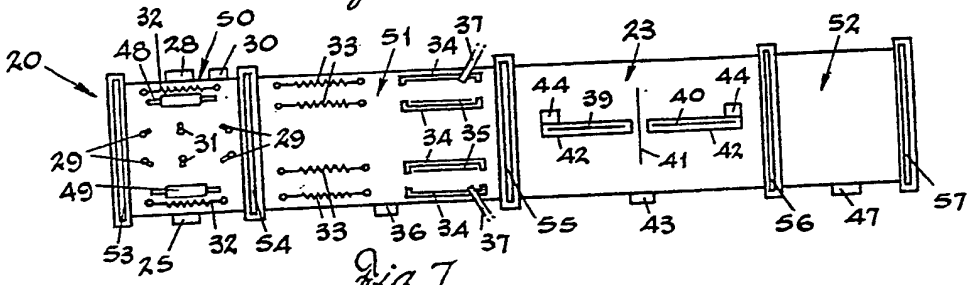

Fig. 7

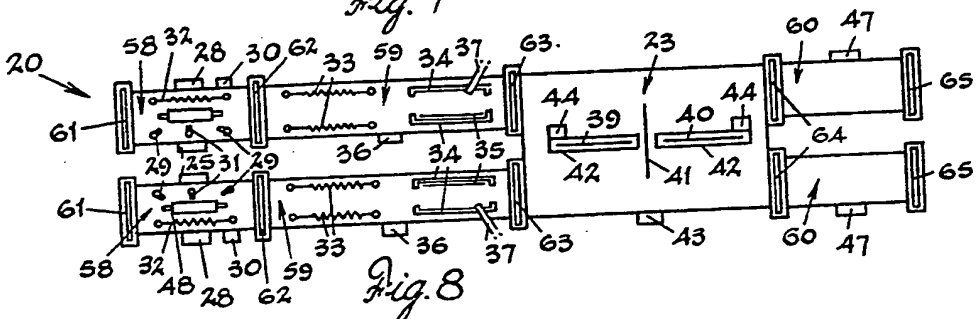

Fig. 8

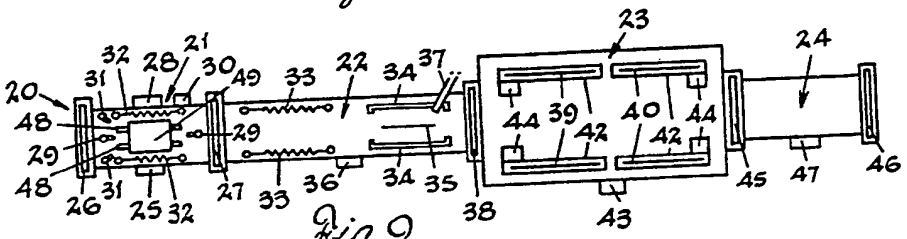

Fig. 9

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2 SHEETS

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SHEETS 1 & 2

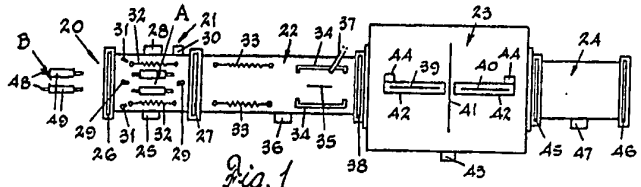

Fig. 1

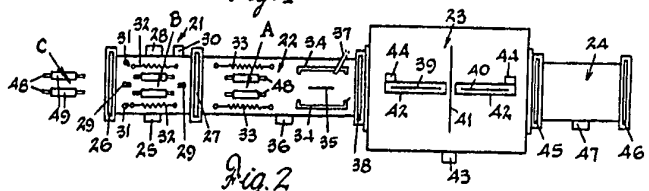

Fig. 2

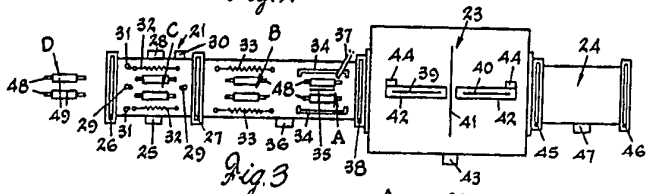

Fig. 3

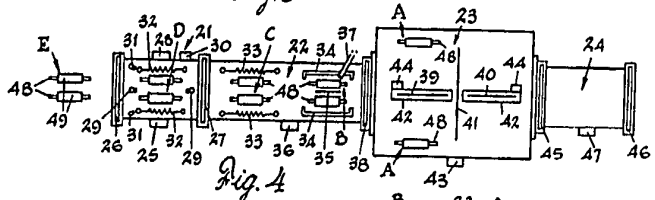

Fig. 4

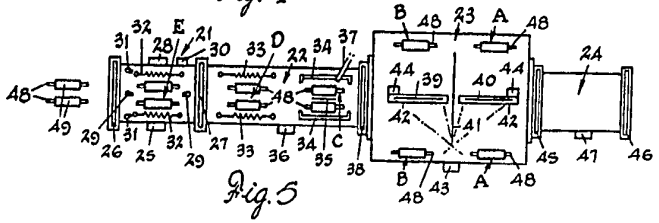

Fig. 5

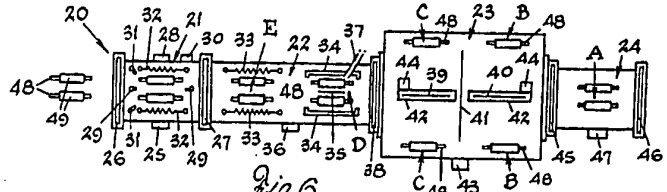

Fig. 6

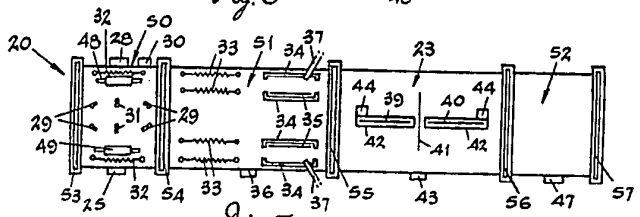

Fig. 7

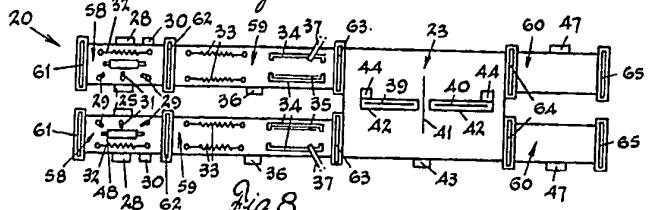

Fig. 8

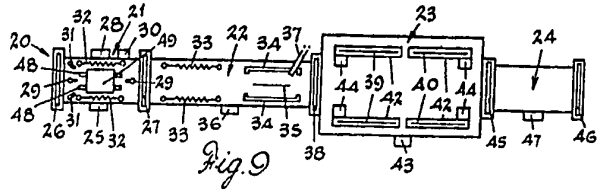

Fig. 9